



Ch.10 Connections – Why is hydrology important?

Introduction

- Modern hydrology study is rarely conducted independently of other natural sciences.
- Hydrology is involved in almost all contemporary scientific environmental problems, e.g., global climate change, acid precipitation, water quality, landscape evolution, groundwater contamination and remediation, the functioning of complex ecosystems, etc.
- Connections among hydrology, ecology, atmospheric sciences, geology

Hydrology and Ecology

- The connection between hydrology and ecology is established through the biogeochemical cycles.
- The biogeochemical cycling is the cycling of nutrients and other chemicals from the abiotic environment through a food chain of organisms and back to the abiotic environment.
- Water is an “universal” solvent and plays a primary role in transporting dissolved and suspended materials through phases of biogeochemical cycles.

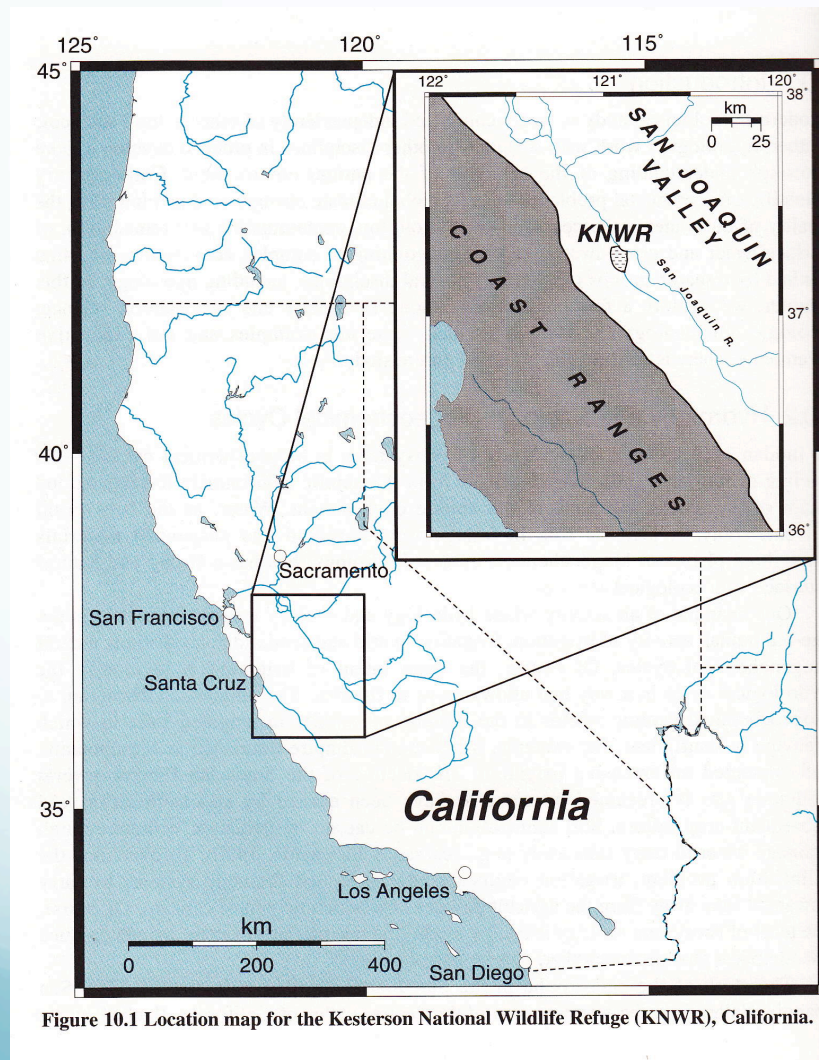
Irrigation Impacts

- The main purpose of irrigation is to modify the hydrological cycle in a way that allow crops to flourish, especially in arid and semiarid regions where precipitation is scarce.
- However, irrigation can disrupt the natural biogeochemical cycles in arid and semiarid areas because of the buildup of salinity in irrigated soils in which drainage is insufficient.

Soil Salinization

- Soil salinization can be caused by irrigation without enough drainage water to carry salts away.
- To overcome the salinization problem, irrigation engineers have designed drainage systems to carry unwanted salts away from the agricultural areas for which they have concern.

The San Joaquin Valley



- Extensive wetlands
- Excellent habitat for fish and birds
- Fertile soils
- More than 90% of the wetlands were converted to agriculture prior to the 1970s.

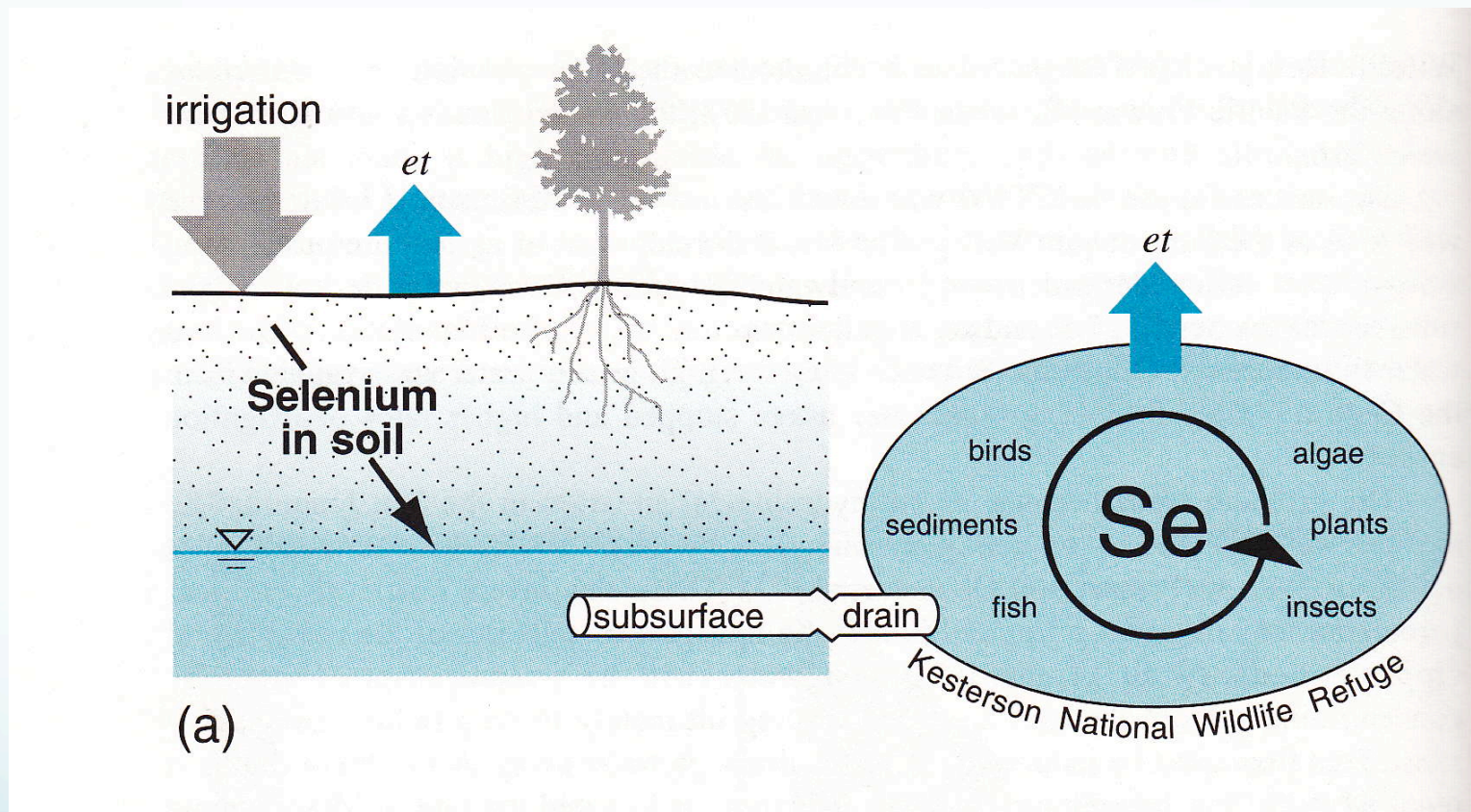
The hydrological situation in the San Joaquin Valley

- 3-12 m beneath land surface, clay layers of very low permeability restrict the vertical percolation of infiltrated water and inhibit the transport of salts out of the root zone of crops.
- In 1960, the San Luis Drain was authorized to construct to transport irrigation drainage waters out of the irrigated area and the original plan was to drain these waters to the Pacific Ocean.
- Lawsuits and costs led to a change: the terminus of the drain became the ponds at the Kesterson National Wildlife Refuge (KNWR).

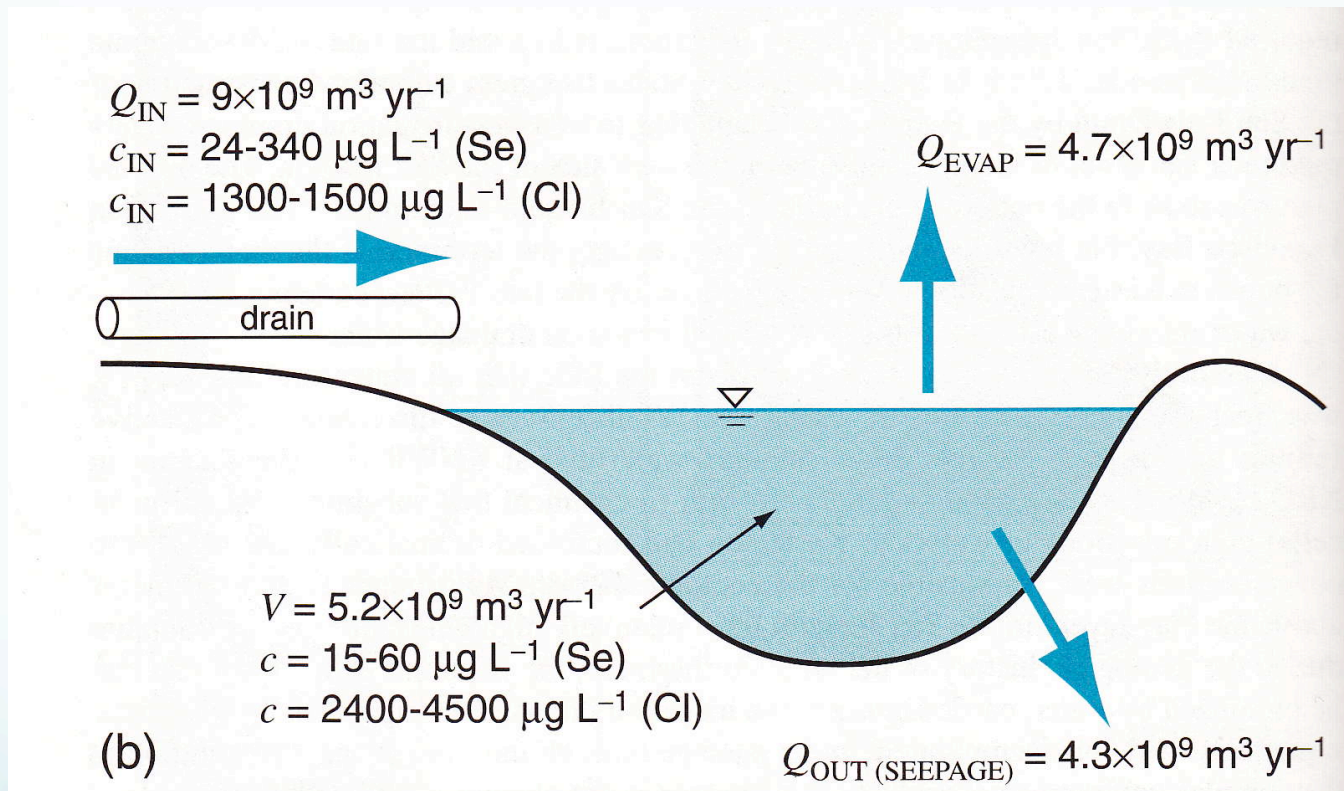
Water Quality at KNWR

- The selenium (a chemical that substitutes for sulfur in cells) concentrations in waters at KNWR had increased dramatically and caused the ecological crisis.
- The selenium is in a form that can be mobilized by water, carried along in the irrigation drainage waters, taken up by aquatic organisms, and “bio-accumulated” in its passage through the food chain.

Biogeochemical cycling of selenium



A simple biogeochemical model



The biogeochemical cycle at KNWR

$$\frac{d(Vc)}{dt} = c_{IN}Q_{IN} - cQ_{OUT} - u_{BIOGEOCHEMICAL}$$

where $u_{BIOGEOCHEMICAL}$ is the rate at which a chemical is removed from solution by biogeochemical processes.

for a steady condition :

$$0 = c_{IN}Q_{IN} - cQ_{OUT} - u_{BIOGEOCHEMICAL}$$

$$u_{BIOGEOCHEMICAL} = c_{IN}Q_{IN} - cQ_{OUT}$$

- Taking c_{IN} as $100 \mu\text{g/L}$ and c as $30 \mu\text{g/L}$ for selenium, $u_{BIOGEOCHEMICAL}$ is about $1.3 \times 10^{11} \mu\text{g/yr.}$
- It was found that in algae the mean concentrations of selenium were $3500\text{-}8500 \mu\text{g/L}$, and in insects and fish were $2200\text{-}17500 \mu\text{g/L}$.

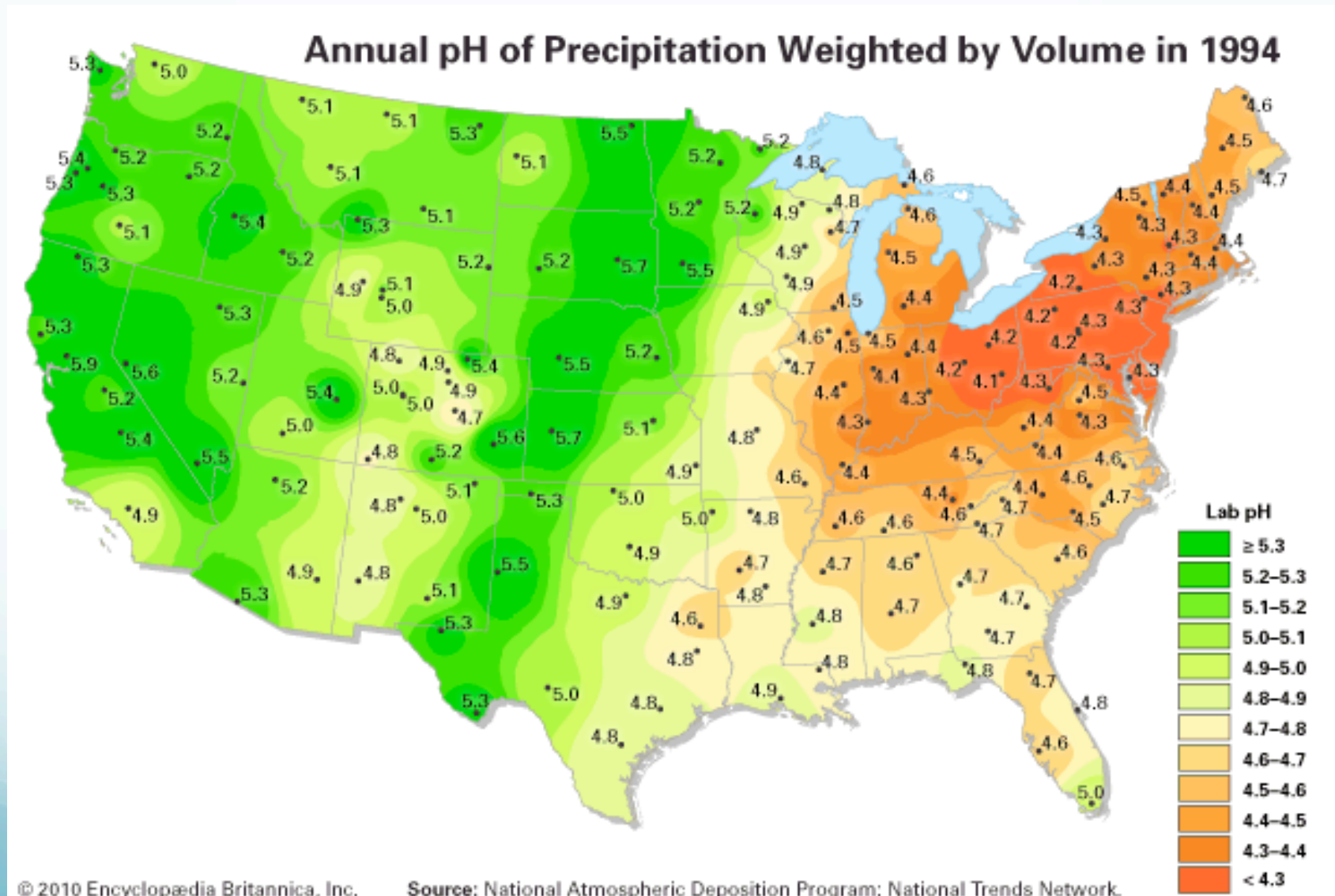
Hydrology and Atmospheric Science

- The terrestrial portion of the hydrological cycles, which is the domain of hydrology, is linked to the atmosphere by exchanges of water and energy at the Earth's surface.
- In addition to being the medium for the exchange of water and energy at the Earth's surface, the atmosphere transports chemicals over long distances and deposits them to the surface of catchments.
- A critical environmental problem related to the long-range atmospheric transport of contaminants and their deposition to catchments is acid deposition, or “acid rain”.

Acid Rain

- The main cause of acid rain is the emission of sulfate into the atmosphere as a results of burning fossil fuels.
- In the atmosphere, the sulfate can react and form sulfuric acid in raindrops.
- The sulfate particles can be transported over long distances with the acid rain falling over broad geographic regions.
- Through much of northeastern and mid-Atlantic regions of the United States, the average pH of rainfall is between 4 and 4.5.

Annual pH of rainfall in 1994



A case study in two small catchments in the Adirondack Mountains of New York

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(a) Panther Lake Basin (neutral)



(b) Woods Lake Basin (acidic)



Figure 10.3 Generalized geological cross sections through Panther Lake Basin (a) and Woods Lake Basin (b). Redrawn from Peters and Murdoch (1985).

- Similar bedrock geology, roughly the same basin size, similar forest vegetation, and received nearly identical atmospheric inputs
- pH value of water in the Panther Lake was near 7.0, and in the Woods Lake was about 4.2.
- Soil depth in the Panther Lake catchment is about 24.5m, and only 2.3 m in the Woods Lake catchment.

Soil Neutralization Effect

- The acid rain is neutralized as the water percolates into the soil.
- The deeper the water goes, the greater the neutralization.
- Soil water in the organic horizon of the Adirondack catchment has a pH of about 3.7. Water at a depth of 0.5m below the land surface has a pH of about 4.5, and pH=6 at the water table, and pH=7.5 at 2.5m below the water table.

Groundwater Recession

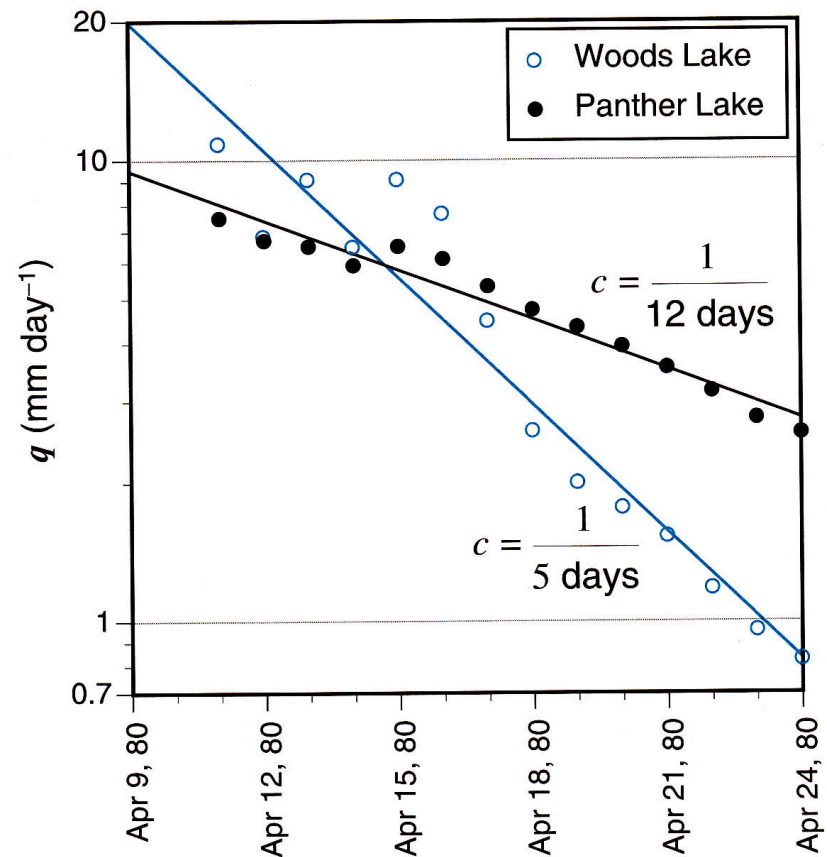


Figure 10.4 Groundwater recession for the Woods Lake and Panther Lake basins. The recession constant, c , is much greater (recession occurs more quickly) for the thin till beneath Woods Lake.

Hydrology and Geology

- Geomorphology, the study of landforms, is intimately tied to hydrology.
- The tectonic processes are largely responsible for elevating the ground surface.
- The surface and subsurface flows of water are responsible for weathering and eroding the landscape, e.g., erosion of the channel bed and banks, landslides, sediment transportation downstream, and etc.
- The landscape is slowly lowered and carved into drainage networks by hydrological and geomorphological processes.

Regions of saturation overland flow, erosion, and landsliding

